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भारतीय मानक

जीवन चक्र लागत

भाग 2 पद्धति विज्ञान

Indian Standard

LIFE CYCLE COSTING

PART 2 METHODOLOGY

UDC 657·471·1·015

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BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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Management and Productivity Sectional Committee, MSD 4

FOREWORD

This Indian Standard was adopted by the Bureau of Indian Standards, after the draft finalized by the Management and Productivity Sectional Committee, had been approved by the Management and Systems Division Council.

With ever increasing investments both by industry and Government together with complications of the continuous explosion in technology, considerable inflation in cost of materials, labour, energy, etc and the changing international and national environments, decisions based on initial costs have often proved to be counter-productive and uneconomical. In particular, where public money is involved, it becomes necessary to ensure the maximum benefits out of every investment. In this situation, a systematic methodology for assessing the total cost of an asset or proposed investment over its entire operating life, particularly to equate various choices open to the decision making authority, becomes essential.

Life cycle costing is a method to arrive at such an economic equitable assessment of competing design alternatives. It takes into account every significant element of cost over the life of the asset and works out its total cost and benefits over its entire economic life.

Economic life is decided in individual cases by the life cycle costing team in an organization taking into account their own experience, experience of others using same or similar equipment, comments of the suppliers, state of the technology, chances of obsolescence etc.

It is alternatively possible to decide comparison of life cycle cost (LCC) only on 5, 10 or 15 years which management considers adequate for comparison purposes, even though the asset may have economic use value far beyond that date. In other words, they have the option to maintain life as fixed for all the alternatives and then calculate the LCC of each alternative for that life.

The calculation of the life cycle cost for the life of an asset exceeding 20 years will be faced with the inevitable uncertainties regarding the actual life of the asset, its sub-assemblies and also the inevitable changes in costs and prices of maintenance, operation, labour and many other inputs. The risks and uncertainties in these factors can be reduced however by simulation exercises and sensitivity studies using a computer. Such procedures are encouraged while using this standard not only for arriving at the LCC but also for the value indices and a comparison thereof before final decisions are made.

This standard does not include methods for measuring the performance for different design choices, equipments or options for investment. If comparison of performance vis-a-vis total life cycle costs, that is, the value index is sought to be arrived at, this standard will help to calculate the denominator only. It is advised that users of this standard should use their own methods for assessing the performance.

Given equal levels of performance, the LCC comparison will itself enable the decisions being made. Where levels of performance vary, the LCC techniques will be able to relate the total life cycle costs to identifiable units of performance in such a way as to enable optimum decisions.

Even after a decision is taken at the initial investment stage or design, several options still exist for use during the initial years or early stages of the asset's life. It is possible to review the various performance or cost parameters vis-a-vis many and frequent changes in technology, input costs and prices etc, and re-evaluate the value index for the old as well as new options that have become available. In such a case, the usage of this standard together with a value index estimation and comparison will still enable new, perhaps radical decisions being made even if it may mean discontinuing part or whole of such assets and replacing them by a new technology altogether. While this may be an extreme possibility, it is by no means rare. Many useful good value medium-level changes in operation and maintenance will be found attractive by utilizing the methods set out in this standard.

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard
LIFE CYCLE COSTING

PART 2 METHODOLOGY

1 SCOPE

This standard prescribes the methodology to work out the life cycle cost (LCC) for each alternative and also methods to compare the life cycle costs for different alternatives. The two methods described in this standard to calculate LCC are Present Worth Method (PW) and Annualised Cost Method (AC).

2 REFERENCES

The following Indian Standard is necessary adjunct to this standard:

IS No.	*Title*
13174 (Part 1) : 1991	Life cycle costing : Part 1 Terminology

3 TERMINOLOGY

For the purpose of this standard, the definitions given in IS 13174 (Part 1) : 1991 shall apply.

4 APPLICATION METHODOLOGY

4.1 The two methods, both equally applicable, may be followed for calculating life cycle cost. One method, known as Present Worth (PW) method, converts all the costs to the present values. The other method, known as Annualised Cost (AC) method, ammortises all costs over the life of the item or project. Both the methods are arithmetically identical. Which method to choose will depend upon the psychology of management in their response to the projected need for funds and the objectives of the LCC team to win management approval to its recommendations. If management are less keen on future actual cost, the PW method should be preferred. The present worth method will also recommend itself where the rate of obsolescence is very high within a short period (say 5 to 10 year). Where there is no major difficulty in finding the funds for initial investment, the attractiveness of future savings in the form of annual costs may prove the AC method to be advantageous.

4.2 The calculation of life cycle cost by both the methods is illustrated with the help of examples.

5 EXAMPLE FROM STEEL INDUSTRY

5.1 A steel company is having four alternatives for producing steel. The company is interested in selecting the alternative which will give the minimum life cycle cost per tonne of production. The four alternatives are as follows:

Alternative I – Continue the existing open hearth steel making process without any change.

Alternative II – Buy the LD process of making steel with having a converter capacity of 70 tonnes per heat.

Alternative III – Buy a latest version of the LD process using a converter of 155 tonnes per heat.

Alternative IV – Buy a larger open hearth plant available second-hand at a lower initial cost and replace it with a new LD process in the fifth year when adequate funds will be available.

For illustrative purposes, it is assumed that the full capacity in each of the above cases will be available in the very first year itself.

5.1.1 The known data in respect of these four alternatives is given in Table 1.

5.2 Present Worth Method

Table 2 gives the life cycle cost for each of the four alternatives by Present Worth (PW) method. This table has been obtained from Table 1 by using the following steps.

5.2.1 Block I of Table 2 shows the total initial cost, which is the same as given in Table 1. This total initial cost is usually incurred within a time span of few months to few years.

5.2.2

a) Block II consists of various single sub-blocks of expenditure, such as, major maintenance schedule at foreseeable periods, for example, 5, 10, 15 and 20 years. Since these involve expenditure at different periods of time, they have to be multiplied by Present Worth Factors (pwf) for converting these values to present worth. For selected values of discount rate (i) and number of years (t), the values of pwf are given in Annex A. For other combination of discount rate and number of years, pwf may be calculated by using the following expression:

PW Factor (pwf) = $(1 + 0.01 \times i)^{-t}$

where

i = discount rate per annum, and
t = number of years.

For example, for i = 12% and t = 5, 10, 15 and 20 years, PW factors are 0.567 4, 0.322 0, 0.182 7 and 0.103 7 respectively (*see* Annex A).

Table 1 Data for Steel Industry

(*Clause* 5.1.1)

Sl No.	Item	Alternative I	Alternative II	Alternative III	Alternative IV
1.	Total initial cost (in million rupees)	367.0	1 887.0	8 434.0	885.0
2.	Production capacity (Average million tonnes per year)	0.28	1.23	1.383	2.25
3.	Operating and maintenance cost per year (in million rupees)	1 041.0	4 023.0	3 213.0	5 625.0
4.	Expected salvage value at the end of the 20th year (in million rupees)	36.7	188.7	421.7	674.3
5.	Economic life	20 years	20 years	20 years	20 years
6.	Recurring annual expenses for years 1 to 4 (in million rupees)	-	-	-	840.0
7.	Single expenditure due to capital repairs at the end of				
	- 5th year	140.0	700.0	Nil	14 100.0
	- 10th year	20.0	100.0	Nil	Nil
	- 15th year	30.0	150.0	Nil	Nil
8.	Rate of escalation for maintenance and operating costs	5% per year	5% per year	5% per year	5% per year
9.	Discount Rate	12%	12%	12%	12%

b) There can be recurring annual expenses but not for the whole life under study (for example, years 1 to 4). In Table 1, for alternative IV, it is mentioned that an expenditure of Rs 840 millions is estimated to be incurred every year for the first four years. Therefore, this expenditure for each year has to be reduced to present worth by multiplying respective pwf (for years 1, 2, 3 and 4) with Rs 840 millions and then adding. Alternatively one can use Uniform Present Worth Factors (upwf) given in Annex B. For example, from Annex B, the value of upwf for discount rate (i) = 12% and number of years (t) = 4 years is given as 3.037 3. Therefore, the total present worth would be Rs 840 millions x 3.037 3 = Rs 2 551 millions. It is shown in Table 2 for alternative IV. For other combinations of i and t, the values of upwf may be obtained from the following expression:

$$\text{upwf} = \frac{b\,(1 - b^t)}{(1 - b)}$$

where

$$b = \frac{1}{(1 + 0.01 \times i)}$$

c) The realization of salvage/disposal at the end of the life of the asset (*see* Table 1) will also have to be reduced to its present worth by multiplying the amount with the corresponding factor given in Annex A. This value has been shown in bracket, indicating that this value has to be subtracted.

d) Add all the present worth values in Block II to get total.

5.2.3 Block III indicates the annual costs of maintenance, operation, energy, labour/staffing and consumables. This annual cost is to be multiplied by upwf (*see* Annex B) to get their equivalent present worth. For example, for i = 12% and t = 20 years, upwf = 7.469 4.

5.2.4 The values of Blocks I, II and III are added to arrive at the life cycle cost (*see* Block IV).

5.2.5 Block V gives the production capacity for each of the alternatives and is taken from Table 1.

5.2.6 Block VI shows life cycle cost per tonne of production. This is obtained as the ratio of the life cycle cost (Block IV) to the production capacity (Block V).

5.2.7 Block VII gives the difference of the LCC per tonne of production for the alternative from the minimum.

5.3 Annualised Cost Method

5.3.1 In this method, all items of expenditure will be annualised or spread over the life of the asset uniformly. Whenever annual items of expenditure are known to be uniform over the entire life, these will require no alterations and can be written as such. The initial cost, the single items of major individual expenses and the actual recurring expenses which are not uniform throughout the life, will all have to be first discounted to present

Table 2 Life Cycle Cost (In Million Rupees) — Present Worth Method

(*Clauses* 5.2 *and* 5.2.1)

Block	Item	Alternative I		Alternative II		Alternative III		Alternative IV	
		Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth
I	*Initial								
	Total initial cost	367.0	367.0	1 887.0	1 887.0	8 434.0	8 434.0	885.0	885.0
II	Salvage and single expenditure :								
	Year 1 to 4, 840/yr x upwf (3.037 3)	-	-	-	-	-	-	840.0	2 551.0
	Year 5, Amt x pwf (for example 140 x 0.567 4)	140.0	79.4	700.0	397.2	-	-	14 100.0	8 000.3
	Year 10, Amt x pwf (for example 20 x 0.322 0)	20.0	6.4	100.0	32.2	-	-	-	-
	Year 15, Amt x pwf (for example 30 x 0.182 7)	30.0	5.5	150.0	27.4	-	-	-	-
	Year 20, Amt x pwf (for example 36.7 x 0.103 7)	(36.7)	(3.8)	(188.7)	(19.6)	(421.7)	(43.7)	(674.3)	(69.9)
	Total		87.5		437.2		(43.7)		10 481.4
III	Annual costs								
	Annual operation and maintenance costs, Amount x upwf (for example 1 041 x 7.469 4)	1 041.0	7 775.6	4 023.0	30 049.4	3 213.0	23 999.2	5 625.0	42 015.4
IV	Life cycle cost	-	8 230.1	-	32 373.6	-	32 389.5	-	53 381.0
V	Production capacity	-	0.28	-	1.23	-	1.383	-	2.25
VI	Cost/Tonne of production	-	29 393.0	-	26 320.0	-	23 420.0	-	23 725.0
VII	Difference in cost/tonne from Minimum	-	5 973.0	-	2 900.0	-	0	-	305.0

Conclusion: Alternative III is more cost advantageous.

* NOTE – The initial cost has been assumed, for illustration purposes, as having spent in the first year, in actual practice, this may be spread over several years. In which case the expenditure in each year will have to be discounted suitably.

worth values by using the applicable PW factors (*see* Annex A). Thereafter, all the present worth values will be totalled and annualised over the entire life to arrive at the comparative annualised cost of the different alternatives. Table 3 gives the life cycle cost, for each of the four alternatives using annualised cost method. This table has been obtained from Table 1 by using the following steps:

a) Blocks I and II of Table 3 are obtained in the same way as for the present worth method (*see* **5.2.1** and **5.2.2**).

b) Block III (a) and III (b) show the total initial cost and salvage and single expenditure cost annualised over the entrie life by using the appropriate ammortisation factors (AF). Ammortisation factors are obtained as reciprocals of upwf given in Annex B. For example, for life of 20 years at 12% discount rate, upwf = 7.469 4. Therefore, AF = 1/upwf = 0.133 9.

c) Block III (c) shows the annual cost of operation and maintenance which is taken from Table 1 and would remain same for all the 20 years of life for all the 4 alternatives. These figures require no change.

d) Block IV shows the total annualised cost and is obtained by adding the values for Blocks III (a), III (b) and III (c).

e) Block V gives the production capacity for each of the alternatives and is taken from Table 1.

f) Block VI shows the annualised cost per tonne of production and is obtained by dividing the total annualised cost (Block IV) by production capacity (Block V).

Table 3 Life Cycle Cost (In Million Rupees) — Annualised Cost Method

(*Clause* 5.3)

Block	Item	Alternative I		Alternative II		Alternative III		Alternative IV	
		Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth
I	*Initial								
	Total initial cost	367.0	367.0	1 887.0	1 887.0	8 434.0	8 434.0	885.0	885.0
II	Salvage and Single Expenditure								
	Year 1 to 4, 840 x upwf (3.037 3)	-	-	-	-	-	-	840.0	2 551.0
	Year 5, Amt x pwf (for example 140 x 0.567 4)	140.0	79.4	700.0	397.2	-	-	14 100.0	8 000.3
	Year 10, amt x pwf (for example 20 x 0.322 0)	20.0	6.4	100.0	32.2	-	-	-	-
	Year 15, Amt x pwf (for example 30 x 0.182 7)	30.0	5.5	150.0	27.4	-	-	-	-
	Year 20, Amt x pwf (for example 36.7 x 103)	(36.7)	(3.8)	(188.7)	(19.6)	(421.7)	(43.7)	(674.3)	(69.9)
	Total		87.5		437.2		(43.7)		10 481.4
III	Annual Owning and Operating Costs :								
	a) Initial capital cost x AF (for example 367 x 0.133 9)		49.1		252.7		1 129.3		118.5
	b) Total replacement costs x AF (for example 87.5 x 0.133 9)		11.7		58.5		(5.9)		1 403.5
	c) Annual cost of operation and maintenance		1 041.0		4 023.0		3 213.0		5 625.0
IV	Total Annualised Cost		1 101.8		4 334.2		4 336.4		7 147.0
V	Production Capacity		0.28		1.23		1.383		2.25
VI	Annual Cost/Tonne of Production		3 935.0		3 524.0		3 135.0		3 176.0
VII	Difference in Annual Cost/Tonne from Minimum		- 800.0		- 389.0		0		- 41.0
VIII	Present Worth of Annual Difference (Difference x 7.469 4)		5 975.0		2 905.0		0		306.0

Conclusion : Alternative III is more cost advantageous.

* NOTE – The initial cost has been assumed, for illustration purposes, as having spent in the first year, in actual practice, this may be spread over several years. In which case the expenditure in each year will have to be discounted suitably.

g) Block VII gives the difference between the annualised cost per tonne of production for the alternative from the minimum.

5.3.2 While the figures in Block VII may themselves be used to make a decision on the choice of alternatives for implementation, it is also possible to highlight this annual saving to the decision making authority by showing what would be the impact of this recurring annual cost benefit in the form of their present worth. This may simply be obtained by multiplying the figures in Block VII by upwf given in Annex B (*see* Block

VIII). It may be noted that the difference in the life cycle cost for the various alternatives will be equal to the figures worked out with present worth method (*see* Table 2). The difference in these values, if any, will be due to the rounding off errors.

5.4 PW Method with Inflation/Deflation

5.4.1 The Present Worth Method and Annualised Cost Method discussed in **5.2** and **5.3** for calculation of life cycle cost, assumed no inflation in 20 years period. But, it is also possible to calculate the life cycle cost by taking into consideration the inflation. For example, Table 1 provides for escalation factor for 'Maintenance and Operating Costs' @ 5% per year. The effect of inflation on LCC calculations will be to increase the present worth of future expenditure. The expression for pwf and upwf in such cases, by taking into consideration both the discount rate (i) and escalation rate (r) for a given time period (t), may be obtained as follows:

$$\text{pwf} = b^t \quad \text{upwf} = \frac{b\,(1 - b^t)}{(1 - b)}$$

where

$$b = \frac{(1 + 0.01r)}{(1 + 0.01i)}$$

For example, for $i = 12\%$, $r = 5\%$ and $t = 20$ years, pwf = 0.275 1 and upwf = 10.87. The present worth of Rs 1 041 million spent every year (Alternative 1 of Table 1) would be 1 041 X 10.87 = Rs 11 315.67 million.

It is also possible to allow for different rates of inflation for different time periods as well as for different items of future estimated expenditures, such as, for material, labour rates, energy rates, etc. In such cases, the methodology would remain the same except that the calculations would be complicated.

5.4.2 The Life Cycle Cost for each of the offers had been calculated with 1991 as the base, but if inflation has to be allowed for, it would increase the present worth. Inflation or deflation rates are neither annual nor consistent and therefore these must be applied for the appropriate periods as per forecast. It may be noted that there are other variables also which cannot be exactly predicted, such as:

a) Maintenance and operation cost year to year,
b) Unscheduled breakdowns,
c) Policy changes, and
d) Extraneous factors.

5.4.2.1 All these aspects fall under the realm of forecasting. There are various statistical/probabilistic/stochastic models which can be prepared for forecasting. Using regression analysis, it is possible for an organization to make a reasonably good prediction and basing decisions purely on current information.

5.4.3 *Example* – Table 4 gives the life cycle costs for each of the 4 alternatives by Present Worth Method (with escalation). This table has been obtained from Table 1 by using the following steps:

a) Since Table 1 provides escalation for 'Maintenance and Operating Costs' only, Block I and II in Table 4 will be obtained in the same way as given in **5.2.1** and **5.2.2** (*see* Blocks I and II of Table 2).
b) As 5 percent inflation in 'Maintenance and Operating Costs' is being assumed, this 5 percent inflation will have to be considered in addition to the 12 percent discount rate and accordingly, the upwf has to be calculated from the expression given in **5.4.1**. The value of upwf comes out to be 10.87 and accordingly the present worth for 'Maintenance and Operating Costs' for each alternative is shown in Block III. It may be noted that the present worth with inflation (as given in Table 4) is much higher than in Table 2.
c) Blocks IV to VII are obtained as given in **5.2.4** to **5.2.7**.

6 EXAMPLE FOR DIESEL ELECTRIC LOCOMOTIVES

This example illustrates the LCC evaluation of competing Indian and international bids for supply of diesel electric locomotives.

The estimation of the initial costs associated with the procurement of the locomotive necessitates the considerable work starting from recognising the need for the additional asset, assessing of detailed technical requirements, preparation of specifications, consultations, global tendering, foreign credit planning, evaluation, contracting, inspection, payments to supplier and final delivery/commissioning. The following assumptions are being made:

a) Need for the additional locomotives established on	D
b) Study of requirements and preparing technical specifications	D + 3 months
c) Preparing global tenders and ensuring foreign exchange /funding	D + 6 months
d) Manufacturing lead time and delivery	D + 15 months
e) Due date for commissioning	D + 2 years
f) Economic life	18 years

Cost estimates and other relevant data for each of the 4 alternative bids to supply diesel electric locomotives is given in Table 5.

6.1 Present Worth Method

Table 6 gives the life cycle cost for each of the 4 alternatives by Present Worth (PW) method. This table has been obtained from Table 5 by using the following steps.

6.1.1

a) Since the costs of studying concepts, feasibility study, etc (Rs 0.2 million) have been incurred in the first three months, they are assumed to be occurred on 01.01.1991 and therefore the same figures have been shown in Block I (a) of Table 6 without any change.

b) The job of scrutinizing the offers received, finalisation of contracts, inspection etc, will take about a year and therefore these costs (Rs 0.3 million) have been converted to present worth by application of the PW Factor applicable for one year (*see* Annex A), that is, 0.3 x 0.909 1 = 0.272 7, which has been shown in Block I (b).

c) The cost of training personnel to operate the locomotives has similarly been calculated by applying the PW Factor 0.8 264 for the period of two years taken for training shown in Block I (c).

d) The purchase cost paid for the locomotives is deemed to have occurred just at the end of the two years and therefore they have been reduced to PW by applying the PW factor 0.826 4 shown in Block I (d).

e) The total initial cost is obtained by adding all the figures in Blocks I (a), I (b), I (c) and I (d) as shown in Block I.

6.1.2 Block II (a) shows various sub-blocks of expenditure on major overhauls, repairs, etc, at foreseeable periods. The period in years of occurrence of these expenditures is counted from 1 January 1991. Since these involve expenditure at different periods of time, the present worth of these expenditures at 10% discount rate have to be calculated by multiplying these expenditures with Present Worth Factors (pwf) for applicable periods as given in Annex A.

a) The realization of sale of scrap at the end of the life of the asset (20 years) as shown in Table 5, will also have to be reduced to its present worth by multiplying the amount with the corresponding factor given in Annex A. This value has been shown in bracket, which indicates that it has to be subtracted.

b) The total of single and salvage costs is given in Block II.

Table 4 Life Cycle Cost (In Million Rupees) — Present Worth Method (With Escalation)

(*Clause* 5.4.3)

Block	Item	Alternative I		Alternative II		Alternative III		Alternative IV	
		Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth
I	*Initial								
	Total initial cost	367.0	367.0	1 887.0	1 887.0	8 434.0	8 434.0	885.0	885.0
II	Salvage & Single Expenditure								
	Year 1 to 4, 840/yr x upwf (3.037 3)	-	-	-	-	-	-	840.0	2 551.0
	Year 5, Amt x pwf (for example 140 x 0.567 4)	140.0	79.4	700.0	397.2	-	-	14 100.0	8 000.3
	Year 10, Amt x pwf (for example 20 x 0.322 0)	20.0	6.4	100.0	32.2	-	-	-	-
	Year 15, Amt x pwf (for example 30 x 0.182 7)	30.0	5.5	150.0	27.4	-	-	-	-
	Year 20, Amt x pwf (for example 36.7 x 1 037)	(36.7)	(3.8)	(188.7)	(19.6)	(421.7)	(43.7)	(674.3)	(69.9)
	Total		87.5		437.2		(43.7)		10 481.4
III	Annual Costs								
	Annual operation and maintenance costs Amount x upwf (for example 1 041 x 10.87)	1 041.0	11 315.67	4 023.0	43 730.01	3 213.0	34 925.31	5 625.0	61 143.75
IV	Life Cycle Cost	-	11 770.17	-	46 054.21	-	43 315.61	-	72 510.15
V	Production Capacity	-	0.28	-	1.23	-	1.383	-	2.25
VI	Cost/Tonne of Production	-	42 036.00	-	37 442.00	-	31 320.00	-	32 227.00
VII	Difference in Cost / Tonne from Minimum		10 716.00		6 122.00		0		907.00

Conclusion: Alternative III is more cost advantageous.

* NOTE – The initial cost has been assumed, for illustration purposes, as having spent in the first year, in actual practice, this may be spread over several years. In which case the expenditure in each year will have to be discounted suitably.

Table 5 Data for Diesel Electric Locomotive (In Million Rupees)

(*Clause* 6)

Sl No.	Item	Japan (Hitachi) Rs	Germany (Henschel) Rs	U.S.A. (General Motors Corpn.) Rs	India (Diesel Locomotives Works) Rs
1.	Railways' cost of studying concept feasibility etc	0.2	0.2	0.2	0.2
1.1	Cost of tendering inspection etc	0.3	0.3	0.3	0.3
2.	Purchase cost per loco	4.5	4.2	6.5	3.7
3.	Cost of training personnel	0.6	0.6	0.9	0.25
4.	Total costs of daily operation over the 18 years' working life (mainly fuel/energy)	12.6	18.0	20.5	16.0
4.1	Average annual cost	0.7	1.0	1.14	0.89
5.	Single expenditure of estimated major repairs/overhaul costs	Yr	Yr	Yr	Yr
5.1		6 0.8	7 0.5	7 0.3	5 0.4
5.2		9 1.1	12 0.5	10 0.7	8 0.4
5.3		11 1.4	17 0.5	14 0.7	11 0.4
5.4		- -	- -	18 0.5	14 0.4
5.5		- -	- -	- -	17 0.4
5.6	Realisation by sale as scrap	20 (0.4)	20 (0.4)	20 (0.4)	20 (0.4)
6.	Discount/Interest rate	10%	10%	10%	10%

Based on quotations suitably checked/modified as per purchaser's assessment, where necessary. Item 5.6 estimated by purchase.

6.1.3 The average annual costs (given in 4.1 of Table 5) have been reduced to present worth by using the relevant uniform present worth factors (upwf) (given in Annex B) and are shown in Block III.

6.1.4 Blocks I, II and III have been added algebraically to arrive at the LCC. The figures are shown in the Block IV.

6.2 Annualised Cost Method

Table 7 gives the life cycle cost for each of the 4 alternatives by annualised cost method. It is compiled on the same lines as Table 4. The method has already been illustrated in Table 1. The uniform annual costs is worked out on the basis of 01.01.1991 base instead of figures having been reduced to PW on 01.01.1991 base as in Table 6. This 'amortization' is only a different method of the same evaluation but will lead to identical results. This is illustrated in Table 7.

6.3 Present Worth Method with Inflation

6.3.1 The inflation rates have been assumed as under:

a) Annual costs of maintenance and operation 5% per year for the first three years, 3% thereafter for six years and 4% thereafter for the entire remaining life of the asset.

b) For single blocks of expenditure :

Japan –	1% per year for the first 10 years and nil thereafter.
Germany –	2% per year for the first five years and 1% for the remaining period.
U.S.A. –	3% per year for the first seven years, 2% for the next eight years and 3% for the remaining period.
India –	5% per year for first 3 years, 3% thereafter for 6 years and 4% thereafter for the remaining period.

6.3.2 The various steps in calculation of LCC (*see* Table 8) are as follows.

6.3.2.1 *Initial cost*

Since **6.3.1** provides escalation for 'Annual costs of maintenance and operation' and 'Single blocks of expenditure' only, Block I in Table 8 for initial cost will be obtained in the same way as given in **6.1.1** (*see* Block I of Table 6).

6.3.2.2 *Single expenditure*

Block II (a) would be calculated by taking the escalation rates as given in **6.3.1** for all the 4 countries separately. This escalation will be taken in addition to the 10% discount rate and accordingly pwf has to be calculated from the expression given in **5.4.1**.

In the case of USA (in Table 8), for i = 10%, t = 18 and r = 3% per year for the first 7 years, 2% for the next 8 years and 3% for the remaining period, the pwf may be calculated as under :

a) Since the rate of escalation is different for different years (with discount rate remaining the same that is 10%), the total period of 18 years has to be divided accordingly, that is,

18 years = (First 7 years @ 3% escalation) and (Next 8 years @ 2% escalation) and (Remaining 3 years @ 3% escalation)

Table 6 Present Worth Method (Base Date 1 January 1991)

(*Clause* 6.1)

Block	Stage in Life Cycle	Japan			Germany			U.S.A.			India		
		Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth
I	a) Concept, feasibility, etc		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0
	b) Tendering to delivery (for example 0.3 x 0.909 1)	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7
	c) Training skills (for example 0.6 x 0.826 4)	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8
	d) Purchase cost/Loco (for example 4.5 x 0.826 4)	2	4.5	3.718 8	2	4.2	3.470 9	2	6.5	5.371 6	2	3.7	3.057 7
	Total Initial Cost			4.687 3			4.439 4			6.340 1			4.026 2
II	a) Single Expenditure	6	0.8	0.451 6	7	0.5	0.256 6	7	0.3	0.154 0	5	0.4	0.248 4
		9	1.1	0.466 5	12	0.5	0.159 3	10	0.7	0.269 9	8	0.4	0.186 6
		11	1.4	0.490 7	17	0.5	0.098 9	14	0.7	0.184 3	11	0.4	0.140 2
		-	-	-	-	-	-	18	0.5	0.090 0	14	0.4	0.105 3
		-	-	-	-	-	-	-	-	-	17	0.4	0.079 1
	b) Disposal cost	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)
	Total			1.349 4			0.455 4			0.638 8			0.700 2
III	Uniform annual costs (for example 0.7 x 8.652)		0.7	6.056 4		1.0	8.652 0		1.14	9.863 3		8.9	7.700 3
IV	Life cycle cost			12.093 1			13.546 8			16.842 2			12.426 7
V	Difference in LCC from minimum			0			1.453 7			4.749 1			0.333 6

= pwf (t = 7 years, r = 3%) x pwf (t = 8 years, r = 2%) x pwf (t = 3 years, r = 3%)

$$\text{pwf} = \left(\frac{1.03}{1.1}\right)^7 \times \left(\frac{1.02}{1.1}\right)^8 \times \left(\frac{1.03}{1.1}\right)^3$$

$$= 0.283\,2$$

Since a single expenditure of 0.5 million will have to be incurred at the end of the 18th year, the present worth of Rs 0.5 million would be 0.5 x 0.283 2 = 0.141 6 million.

b) Likewise, the remaining values for the other countries can be calculated in the same way.

6.3.2.3 Since there is no escalation on disposal cost, Block II (b) will be calculated in the same way as in Table 6.

6.3.2.4 Block II would be obtained by adding II (a) and II (b).

6.3.2.5 In Block III, the time lapse between establishing the need for the machine and the date of commissioning of the machine is 2 years. In addition, the economic life of the machine is given as 18 years. Hence, the entire annual cost of the machine would be calculated on 20 years time period (*see* **6.3.1**).

The expression for pwf and upwf for a given discount rate (i), escalation rate (r) and period (t) is given in **5.4.1**. For example, upwf (i = 10%, r = 4%, t = 11 years)

$$= \frac{b\,(1 - b^t)}{1 - b} = 8.447\,7$$

where b = (1 + 0.04) / 1.1

Therefore, upwf for uniform annual cost

= upwf(11 yr at 4% escalation) x pwf (6 yr at 3% escalation) x pwf (3 yr at 5% escalation) + upwf (6 yr at 3% escalation) x pwf (3 yr at 5% escalation) + upwf (3 yr at 5% escalation)

= 8.447 7 x 0.674 0 x 0.869 7 + 5.122 9 x 0.869 7 + 2.866 6 = 12.273 8

6.3.2.6 Block IV could be calculated by adding Blocks I, II and III.

Table 7 Annualized Cost Method (Base Date 1 January 1991)

(*Clause* 6.1)

Block	Stage in Life Cycle	Japan			Germany			U.S.A.			India		
		Year	Esti-mated Cost	Present Worth	Year	Estima-ted Cost	Present Worth	Year	Esti-mated Cost	Present Worth	Year	Esti-mated Cost	Present Worth
I	a) Concept, feasibility etc		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0
	b) Tendering to delivery (for example 0.3 x 0.909 1)	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7
	c) Training skills (for example 0.6 x 0.826 4)	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8
	d) Purchase cost/Loco (for example 4.5 x 0.826 4)	2	4.5	3.718 8	2	4.2	3.470 9	2	6.5	5.371 6	2	3.7	3.057 7
	Total Initial Cost			4.687 3			4.439 4			6.340 1			4.026 2
II	a) Single Expenditure	6	0.8	0.455 6	7	0.5	0.256 6	7	0.3	0.154 0	5	0.4	0.248 4
		9	1.1	0.466 5	12	0.5	0.159 3	10	0.7	0.269 9	8	0.4	0.186 6
		11	1.4	0.490 7	17	0.5	0.098 9	14	0.7	0.184 3	11	0.4	0.140 2
		-	-	-	-	-	-	18	0.5	0.090 0	14	0.4	0.105 3
		-	-	-	-	-	-	-	-	-	17	0.4	0.079 1
	b) Disposal cost	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)
	Total			1.349 4			0.455 4			0.638 8			0.700 2
III	Annual owning and operatring cost :												
	a) TIC*AF (4.687 3 * .117 5)			0.550 8			0.521 6			0.745 0			0.473 1
	b) TRC*AF (1.349 4 * .117 5)			0.158 6			0.053 5			0.075 1			0.082 3
	c) Annual cost of operation over the 18 years working life			0.700 0			1.000 0			1.140			0.890 0
	d) Annualized cost			1.409 4			1.575 1			1.960 1			1.445 4
IV	Diffrerence in annual cost from minimum			0			0.165 7			0.550 7			0.036
V	PW of the annual cost (Diff.* 8.513 6)						1.410 7			4.688 4			0.306

6.4 It is assumed that all the 4 offers :

a) will cater for the specified tonne-kilo-metres identically,

b) have identical working life (18 years) , and

c) are identical in other aspects as well, such as, ease of maintenance, accessibility, indigenisability, export potential (after manufacturing the locomotives in India) etc.

6.4.1 There are extant methods to arrive at a numerical assessment of the total functional performance of any asset, considering the factors stated above or similar ones. They are appropriate in varying degrees to different types of assets such as buildings, bridges, hydraulic works, machinery, industrial projects etc, but none of them is or can be totally accurate, even as no forecasting of inflation can be accurate. Nevertheless, such important factors can be quantified in numerical terms to the possible extent, for example annual average Gross Tonne Kilo Metre (GTKM) expected to be hauled by the locomotives, namely

Japanese offer

16 h x 40 km x 300 days x 1500 *t*

Table 8 Present Worth Method With Escalation (Base Date 1 January 1991)

(*Clause* 6.3.2)

Block	Stage in Life Cycle	Japan			Germany			U.S.A.			India		
		Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth	Year	Estimated Cost	Present Worth
I	a) Concept, feasibility, etc		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0		0.2	0.200 0
	b) Tendering to delivery (for example 0.3 x 0.909 1)	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7	1	0.3	0.272 7
	c) Training skills (for example 0.6 x 0.826 4)	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8	2	0.6	0.495 8
	d) Purchase cost/Loco (for example 4.5 x 0.826 4)	2	4.5	3.718 8	2	4.2	3.470 9	2	6.5	5.371 6	2	3.7	3.057 7
	Total Initial Cost			4.687 3			4.439 4			6.340 1			4.026 2
II	a) Single Expenditure	6	0.8	0.479 4	7	0.5	0.289 0	7	0.3	0.189 3	5	0.4	0.305 0
		9	1.1	0.510 9	12	0.5	0.188 6	10	0.7	0.352 2	8	0.4	0.250 4
		11	1.4	0.542 1	17	0.5	0.123 0	14	0.7	0.260 4	11	0.4	0.209 6
		-	-	-	-	-	-	18	0.5	0.141 6	14	0.4	0.177 1
		-	-	-	-	-	-	-	-	-	17	0.4	0.149 7
	b) Disposal cost	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)	20	(0.4)	(0.059 4)
	Total			1.473 0			0.541 2			0.884 1			1.032 4
III	Uniform annual costs (for example 0.7 x 12.273 8)		0.7	8.591 7		1.0	12.273 8		1.14	13.992 1		8.9	10.923 7
IV	Life cycle cost			14.752 0			17.254 4			21.216 3			15.982 3
V	Difference in LCC from minimum			0			2.502 4			6.464 3			1.230 3

German offer

14 h x 46 km x 300 days x 1 000 *t*

US offer

12 h x 40 km x 270 days x 2 000 *t*

Indian offer

10 h x 30 km x 250 days x 1 000 *t*

7 EXAMPLE FROM BUILDING INDUSTRY

In building industry, the common practice in India of Life Cycle Cost Analysis is to work out the life cycle cost of various alternatives of individual elements rather than working out LCC of building as a whole. This helps in selecting different combinations of alternatives from various elements. After having the LCC of different alternatives of all the elements, a combination consisting of one alternative from each element may be selected to give the minimum Life Cycle Cost for complete building.

The following example depicts the selection of type of doors out of three alternatives for residential buildings say, 40 tenements of 75m^2 plinth area each.

Alternative 1 – 1st class teak wood frame and shutters.

Alternative 2 – 1st class deodar wood frame and shutters.

Alternative 3 – Steel door frame with shutters of secodary species of timber and plywood paneling.

The cost data information in respect of these alternatives are given in Table 9.

The Economical Life of three alternatives is given in the table. But the Life Cycle Costing has been worked for a life span of 20 years, a period for which reasonable prediction could be made.

Salvage/scrap value has been assumed based on the utility of the product at the end of 20 years.

The single expenditure to be incurred at the end of 10 years pertains to the major repairs to be effected for

Table 9 Data for Building Industry

(*Clauses* 7 *and* 7.1.1)

Sl No.	Item	Alternative I	Alternative II	Alternative III
1	Total initial cost (Rs)	800 000	500 000	350 000
2	Repair cost (Annual) (Rs)	2 000	8 000	12 000
3	Periodical maintenance (Annual) (Rs)	6 000	8 000	8 000
4	Economical life of component (Years)	50	30	20
5	Single expenditure at the end of 10 years (Rs)		60 000	100 000
6	Salvage value after 20 years (Rs)	300 000	40 000	20 000
7	Discount rate	12%	12%	12%

replacing worn out parts of the joinery. Periodical maintenance given in the table is meant for doing the routine annual painting/polishing work to the joinery. These are average annual figures.

The annual cost of repairs, as given in the table, have been computed with the help of data given in Annex C. The data given in this Annex, which is for illustrative purposes only, is applicable for northern part of the country and is based on 1989-90 price level for a given type of construction. This cost information can be updated for price level at any future date with the help of maintenance cost indices which can be worked out using weightage diagram given in Annex D. The procedure of computing the maintenance cost index as given in the Annex is self explanatory.

7.1 Present Worth Method

7.1.1 The LCC has been worked out using present worth method only and the inflation in cost has not been considered for simplification purpose. Table 10 gives the Life Cycle Cost for each of the three alternatives. The computation has been based on the cost information/data given in Table 9 :

a) Block I gives the initial cost of each of the alternatives.

b) Block II consists of single expenditure to be incurred after a period of 10 years. The present worth of each expenditure has been worked out using present worth factors (pwf) using expression as given in **5.2.2** with 12 percent discount rate. The present worth of salvage/scrap value has also been computed on the same basis and is represented by bracketed figures which has to be subtracted.

c) Block III indicates the costs of annual repairs and consumables and periodical maintenance as per sum of item No. 2 and 3 of Table 9. The present worth has been computed using the uniform present worth factors (upwf) as given in **5.2.3.**

d) Block IV gives the total life cycle cost derived from Blocks I, II and III.

8 PRECAUTIONS WHILE CALCULATING LCC

While applying the LCC techniques one must take into account :

a) The price of services since these are likely to change over a period of time; some consistency over short periods, such as, six months or one year shall be assumed to make the calculations worthwhile and realistic.

b) What applies to expenses and costs in terms of the time value money will equally apply to earnings and profits during the operation and use of the assets. Corresponding tables must be prepared using this standard and the associated discount factor tables to arrive at such earnings/profits.

c) Estimation of costs and earnings must be made taking into account the past data which should be analyzed using statistical aids, simulation methods, and forecasting techniques so as to make the LCC comparison as realistic as possible. For this purpose, LCC comparisons covering a lesser period of at the most five years, would be more reliable than for 15 years, that is the longer the period the less the accuracy. Computer systems can be developed to review the position from time to time. It is advisable for management to review the positions annually and review their decisions, if not in initial investment at least in operation/maintenance/replacement or extensive modifications subsequently. Such reviews may also influence the economic life.

d) An important assumption made so far is that all the alternatives will provide equal quality/performance/productivity over the assumed 20 years life cycle. In fact, in many cases, none of these aspects will be exactly equal. In such a case, the life cycle costs will have to be calculated on parametric basis, that is unit rate basis. The existing methods of business acumen/intuition/probability calculations will have to be

Table 10 Life Cycle Cost (Rs) Using Present Worth Method

(*Clause* 7.1.1)

Block	Item	Alternative I		Alternative II		Alternative III	
		Estimated Cost	Present Worth	Estimated Cost	Present Worth	Estimated Cost	Present Worth
I	*Initial	800 000	800 000	500 000	500 000	350 000	350 000
	Total Initial Cost						
II	Salvage & Single Expenditure						
	a) Expenditure after 10 years Amt x pwf = (Amt x 0.322 0)	--	-	60 000	19 320	100 000	32 200
	b) Salvage after 20 years Amt x pwf = (that is 300 000 x 0.103 7)	(300 000)	(31 110)	(40 000)	(4 148)	(20 000)	(2 074)
	Total		(31 110)		15 172		30 126
III	Annual cost						
	(Repair and Periodical Maintenance) Amt x upwf (8 000 x 7.469 4)	8 000	59 755	16 000	119 510	20 000	149 388
IV	Life Cycle Cost	-	828 645	-	634 682	-	529 514

Conclusion : Alternative III is more cost advantageous.

*NOTE – The initial cost has been assumed, for illustration purposes, as having spent in the first year, in actual practice, this may be spread over several years. In which case the expenditure in each year will have to be discounted suitably.

resorted to with information from variety of Government or private sources as applicable to arrive at the expected trends during the estimated life for each of the alternatives.

e) Different discount rates have been chosen in this standard for illustrative purposes only. In actual application, the discount rate must be carefully chosen keeping in view the type and nature of industry, the overall price indices in the country and the prevailing rates of cost of capital.

9 SELECTION OF AN ALTERNATIVE

9.1 Prime facie, the alternative which is the least in Life Cycles Cost for equal life period/performance rating will automatically be selected.

9.2 However, some of the alternatives may have life cycle costs close to each other and the difference may not be significant. In such cases, the decision maker has the option of choosing an alternative which may be marginally superior in respect of certain factors, such as, accessibility, less retraining of workers, no necessity for import etc. It may be noted that the word 'marginal' is important as otherwise the original estimation was that LCC have been calculated for equal level of performance or on parametric basis. This will be vitiated if the total performance ratings are substantially different for the various alternatives.

9.3 The decision maker may also look for imaginative or scientific ways to improve the LCC. In fact, a scrutiny of the life cycle cost comparison may motivate the generation of a large number of ideas in order to maximize the performance/reduce cost or achieve both.

ANNEX A

(*Clause* 5.3.1)

PRESENT WORTH FACTORS (pwf) FOR SELECTED VALUES OF DISCOUNT RATE AND NUMBER OF YEARS

$$\text{pwf} = \frac{1}{(1 + 0.01 \times i)^t}$$

Year (*t*) Discount Rate (%) (*i*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10.0	.909 1	.826 4	.751 3	.683 0	.620 9	.564 5	.513 2	.466 5	.424 1	.385 5	.350 5	.318 6	.289 7	.263 3	.239 4	.217 6	.197 8	.179 9	.163 5	.148 6
10.5	.905 0	.819 0	.741 2	.670 7	.607 0	.549 3	.497 1	.449 9	.407 1	.368 4	.333 4	.301 8	.273 1	.247 1	.223 6	.202 4	.183 2	.165 8	.150 0	.135 8
11.0	.900 9	.811 6	.731 2	.658 7	.593 5	.534 6	.481 7	.433 9	.390 9	.352 2	.317 3	.285 8	.257 5	.232 0	.209 0	.188 3	.169 6	.152 8	.1377	.124 0
11.5	.896 9	.804 4	.721 4	.647 0	.580 3	.520 4	.466 7	.418 6	.375 4	.336 7	.302 0	.270 8	.242 9	.217 8	.195 4	.175 2	.157 2	.140 9	.126 4	.113 4
12.0	.892 9	.797 2	.711 8	.635 5	.567 4	.506 6	.452 3	.403 9	.360 6	.322 0	.287 5	.256 7	.229 2	.204 6	.182 7	.163 1	.145 6	.130 0	.116 1	.103 7
12.5	.888 9	.790 1	.702 3	.624 3	.554 9	.493 3	.438 5	.389 7	.346 4	.307 9	.273 7	.243 3	.216 3	.192 2	.170 9	.151 9	.135 0	.120 0	.106 7	.094 8
13.0	.885 0	.783 1	.693 1	.613 3	.542 8	.480 3	.425 1	.376 2	.332 9	.294 6	.260 7	.230 7	.204 2	.180 7	.159 9	.141 5	.125 2	.110 8	.098 1	.086 8
13.5	881 1	.776 3	.683 9	.602 6	.530 9	.467 8	.412 1	.363 1	.319 9	.281 9	.248 3	.218 8	.192 8	.169 8	.149 6	.131 8	.116 2	.102 3	.090 2	.079 4
14.0	.877 2	.769 5	.675 0	.592 1	.519 4	.455 6	.399 6	.350 6	.307 5	.269 7	.236 6	.207 6	.182 1	.159 7	.140 1	.122 9	.107 8	.094 6	.082 9	.072 8

ANNEX B

(Clauses 5.3.1 *and* 5.3.2)

UNIFORM PRESENT WORTH FACTORS (upwf) FOR SELECTED VALUES OF DISCOUNT RATE AND NUMBER OF YEARS

$$\text{upwf} = \frac{b\,(1 - b^t)}{(1 - b)}, \qquad \text{where } b = \frac{1}{(1 + 0.01 \times i)}$$

Year (t) Discount Rate (%) (i)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
10.0	0.909 1	1.735 5	2.486 9	3.169 9	3.790 8	4.355 3	4.868 4	5.334 9	5.759 0	6.144 6	6.495 1	6.813 7	7.103 4	7.366 7	7.606 1	7.823 7	8.021 6	8.201 4	8.364 9	8.513 6
10.5	0.905 0	1.724 0	2.465 1	3.135 9	3.742 9	4.292 2	4.789 3	5.239 2	5.646 3	6.014 8	6.348 2	6.650 0	6.923 0	7.170 2	7.393 8	7.596 2	7.779 4	7.945 1	8.095 2	8.230 9
11.0	0.900 9	1.712 5	2.443 7	3.102 4	3.695 9	4.230 5	4.712 2	5.146 1	5.537 0	5.889 2	6.206 5	6.492 4	6.749 9	6.981 9	7.190 9	7.379 2	7.548 8	7.701 6	7.839 3	7.963 3
11.5	0.896 9	1.709 1	2.437 4	3.092 5	3.682 0	4.212 3	4.689 4	5.118 7	5.504 9	5.852 4	6.165 0	6.446 2	6.699 3	6.926 9	7.131 7	7.316 0	7.481 8	7.630 9	7.765 1	7.885 8
12.0	0.892 9	1.690 1	2.401 8	3.037 3	3.604 8	4.111 4	4.563 8	4.9676	5.3282	5.650 2	5.937 7	6.194 4	6.423 5	6.628 2	6.810 9	6.974 0	7.119 6	7.249 7	7.365 8	7.469 4
12.5	0.888 9	1.679 0	2.381 3	3.005 6	3.560 6	4.053 8	4.492 3	4.882 0	5.228 5	5.536 4	5.810 2	6.053 5	6.269 8	6.462 0	6.632 9	6.784 8	6.919 8	7.039 8	7.146 5	7.241 4
13.0	0.885 0	1.668 1	2.361 2	2.974 5	3.517 2	3.997 5	4.422 6	4.798 8	5.131 7	5.426 2	5.686 9	5.917 6	6.121 8	6.302 5	6.462 4	6.603 9	6.729 1	6.839 9	6.938 0	7.024 8
13.5	0.881 1	1.657 3	2.341 3	2.943 8	3.474 7	3.942 5	4.354 6	4.717 7	5.037 7	5.319 5	5.567 9	5.786 7	5.979 4	6.149 3	6.298 9	6.430 8	6.546 9	6.649 3	6.739 5	6.818 9
14.0	0.877 2	1.646 7	2.321 6	2.913 7	3.433 1	3.888 7	4.288 3	4.638 9	4.946 4	5.216 1	5.452 7	5.660 3	5.842 4	6.002 1	6.142 2	6.2651	6.372 9	6.467 4	6.550 4	6.623 1

NOTE : $\text{AF} = \frac{1}{\text{upwf}}$

ANNEX C

(*Clause* 7)

MAINTENANCE COST OF VARIOUS SPECIFICATIONS

(Cost in Rupees Per Year)

Base Year 1989-90

Elements/Specifications (1)	*Unit* (2)	*Cost of Maintenance (Annual)* (3)
1. Plastering:	m^2 of Plaster	
(i) Cement Plaster in CM 1 : 6, 15 mm thick		0.32
(ii) Lime *SURKHI* Plaster in LS 1 : 2, 15 mm thick		0.26
2. Flooring:	m^2 of Floor	
(i) Indian Patent Stone Flooring 40 mm thick		1.15
(ii) Marble Chips Flooring 40 mm thick		0.33
3. Roof Terracing:	m^2 of Terrace	
(i) 10 cm thick Mud *PHUSKA* with Brick Tiles on Top		1.18
(ii) 10 cm thick Lime Concrete Terrace with Brick Tiles on Top		0.80
(iii) 10 cm Thick Lime Concrete Terrace		1.15
4. Joinery:	m^2 of Opening	
(i) Teak Wood Frame and 40 mm thick Teak Panelled Shutter		2.85
(ii) Teak Wood Frame and 40 mm thick Decorative Type Flush Shutters		2.10
(iii) Sal Wood Frame and 40 mm thick Non-Decorative Type Flush Shutters		9.70
(iv) Deodar Wood Frames and 40 mm thick Deodar Panelled Shutters		8.45
(v) M.S. Iron Frame and 35 mm thick Deodar Shutters with Ply Panels		9.15
5. Storage Tank - 270 litres Capacity:	Each	
(i) M.S. Sheet Tank		42.0
(ii) R.C.C. Tank		36.0
(iii) A.C. Tank		28.0
6. Door and Window Fittings:	m^2 of Shutter	
(i) Brass Fittings		0.50
(ii) M.S. Fittings		0.95
(iii) Aluminium Fittings		0.75

ANNEX D

(*Clause* 7)

WEIGHTAGE DIAGRAM FOR COMPUTATION OF MAINTENANCE COST INDEX FOR BUILDING

Material and Labour	*Unit*	*Rate 1989*	*Weight*	*Maintenance Cost Index, 1991*	
				Rate	Modified Weight
Cement	Tonne	928.43	4.5	1 600.00	7.8
Sand	m^3	75.24	2.5	100.00	3.3
Timber	m^3	9 696.60	13.0	12 000.00	16.1
Glass	m^2	73.50	4.0	80.00	4.4
Bib/Stop Cock	Each	27.00	11.0	35.00	14.3
WC Seat	Each	110.00	2.0	150.00	2.7
Skilled Labour	Man day	33.20	38.0	50.00	57.2
Unskilled Labour	Man day	21.60	25.0	35.00	40.0
			100.0		146.3

Maintenance Cost Index in 1991 with respect to basic year 1989 = 146.3

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